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CIM – A MANUFACTURING PARADIGM

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CIM - A MANUFACTURING PARADIGM

LE CIM - UN NOUVEAU MODELE INDUSTRIEL

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ABSTRACT

The Industrial Revolution was based on the paradigm of the "division of labour" into areas of specialization. Manufacturers and, indeed, most enterprises have refined the "Industrial Revolution" model - we live in the age of the specialist. However, the "specialist" model has reached its limit for improving productivity. Direct manufacturing costs represent only a small percentage of total production cost; indirect or manufacturing support costs are a very large fraction of total cost. CIM, Computer Integrated Manufacturing is a new paradigm which promotes the integration of organization, planning and control to improve productivity by maintaining a single manufacturing record. This new paradigm will greatly reduce manufacturing support costs.

This paper presents examples of the CIM paradigm and discusses the John Deere Tractor Works as an instance of the CIM model. Also discussed are some prevalent myths about CIM and some of the key concepts. A prognosis is given, based on the productivity improvement anticipated from a wide adoption of the CIM paradigm.

RÉSUMÉ

La Révolution industrielle a été fondée sur le modèle de la "division du travail" en domaines de spécialisation. L'industrie, et de fait la plupart des entreprises, ont affiné le modèle de "Révolution industrielle". Nous vivons à l'époque du spécialiste. Toutefois, le modèle de spécialisation a atteint le point au-delà duquel on ne peut plus améliorer la productivité. Les coûts directs de fabrication ne représentent qu'un faible pourcentage des coûts totaux de production; les coûts indirects ou de soutien à la fabrication représentent une très grande proportion du coût total. Le CIM est un nouveau modèle, qui sert à promouvoir l'intégration de l'organisation, de la planification et de la réglementation comme solution au problème d'amélioration de la productivité; il s'agit de garder un seul système d'enregistrement des données sur la fabrication. Ce nouveau modèle permettra de grandement réduire les coûts de soutien à la fabrication.

Dans cet article, on donne des exemples du modèle, et l'on cite l'usine de tracteurs John Deere comme exemple d'usine fondée sur un modèle CIM. On commente aussi certains mythes relatif du CIM, et quelques-uns des concepts clés du CIM. On formule un prognostic découlant de l'amélioration de la productivité, qui résulteraient de l'adoption à grande échelle du modèle CIM.

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CIM - A MANUFACTURING PARADIGM

Science and engineering and indeed the whole world of technical speech has become flooded with acronyms: Computer Aided Design, Computer Aided Manufacturing, Computer Aided Engineering, CAD, CAM, CAE, PC, CAPP, etc. In the last decade, the world of manufacturing has been afflicted with this disease. CIM, Computer Integrated Manufacturing: is this merely another acronym for a set of technological tools applied to manufacturing? This paper would suggest that it is not, but that it represents a real shift in thinking, a new paradigm for manufacturing with great potential to improve productivity.

1.0 THE CIM PARADIGM

In 1776 Adam Smith described, in his book The Wealth of Nations (Smith, 1961), the change in paradigms for manufacturing during the first Industrial Revolution: "the greatest improvement in the productive powers of labour ... seem[s] to have been the effects of the division of labour." The old paradigm for manufacturing was that a product was made by a single craftsman (or a group of craftsmen directed by one master craftsman). The paradigm which improved productivity for the Industrial Revolution was the decentralization of skill and knowledge into areas of specialization. A product was made by a sequence of fixed steps; each step was done by a craftsman with specialized skills. This model has been perfected over the last two centuries. Craftsmen have been replaced or assisted by machines for speed and efficiency, and the degree of specialization and standardization has been increased in the sense of both narrowness and refinement. Manufacturing processes, business procedures, building trades, even service and repair functions have been broken down into sequences of small tasks and people are trained in special skills for only these tasks.

Computer Integrated Manufacturing would promote a new paradigm to be used by manufacturers; the control of manufacturing through the use of a single master record for all manufacturing information. This master record contains all the information necessary to make the products; not just manufacturing data, but also business procedures, corporate goals and management structure, i.e. the complete architecture of an enterprise. Changes to the master record will immediately reflect new products, new processes or new procedures.

The solutions to major problems in manufacturing today are not to be found by increasing the efficiency in each step of production, from sales order to packing slip, but by improving coordination and control between the steps of the process. In today's manufacturing, direct production costs have been reduced to a small fraction of total product cost. Direct labour in today's electronics industry accounts for 5% to 8% of production cost. IBM's direct labour cost is about 4%; at Apple's new Macintosh plant it is 1%. Indirect costs, that is manufacturing support costs, are the large items. The Industrial Revolution's model of specialization has, today, been carried to an extreme where specialists are very efficient; however, support systems

need to be streamlined in order to reduce disproportionate overhead costs, i.e. in process inventories, excessive management structure, large numbers of machine tools.

Computer Integrated Manufacturing, with the emphasis on the word 'Integrated', introduces a new paradigm to reduce support costs and to develop a new concept of manufacturing.

Does a new paradigm improve productivity? It is instructive to examine the recent developments in banking. In the 1960's a customer doing business in a bank did so through the use of an account card. The paradigm was that of an individual account register for each customer which was held at a branch bank. Tellers wrote each transaction on the account card. At the end of the week, items from the account card were transferred to the branch's registry and a copy of the registry was forwarded to the main branch. All such registers were again copied into a master register. The information in the master register enabled planning and business decisions to be made by central management.

The model on which bank operations are now based is that of a single bank register. This new paradigm changed, not the actual business of a bank, but the manner in which business was done. The 'bank register' was held on a central computer, with all transactions indicated via specialized computer terminals. The employees at the bank's main office could make more informed investment decisions, which in turn made the bank more money. Account balances, monies deposited, borrowed, or owed could be calculated instantaneously; there was no waiting for weeks while accountants transcribed and determined register tallies. Banking changed and the impact on the customer was profound: service at any branch, branch to branch transfers, automatic tellers, banking cards and instantly accessible credit. The road to improved productivity and service was not honing an old paradigm but adopting a new one.

In CIM the new paradigm promotes the integration of organization, planning and control to improve productivity by maintaining a single, manufacturing record. On a recent Canadian Advanced Manufacturing Technologies Mission to Japan, it became very clear to the mission's members that technology itself is not the answer.Large gains in productivity are not achieved by introducing Robots, Automatic Storage and Retrieval Systems, Automatically Guided Vehicles, Numerically Controlled Machines, Programmable Controllers, or any other component of automation. Each of these technologies improves only an area of specialization. While computers provide the mechanism it is the paradigm, and the understanding of the implications of the paradigm that lead to better manufacturing planning, and hence, to improved productivity.

2.0 HISTORICAL PERSPECTIVE

In 1946, a revolutionary paper was written by Eric Leaver and John Brown, "Machines Without Men" (Leaver et. al. 1946, Fortune 1946). They proposed 'an automatic factory' where machines controlled by computers could make products, from the design concept to product shipping, without men. 1946 was the year ENIAC was delivered to MIT;

Leaver and Brown had a truly remarkable vision. They proposed that machine specialization should be oriented to function rather than product. They proposed three types of machines for a fully automatic factory: " (i) to give and receive information, (ii) to control through collation, and (iii) to operate on materials".

Some of the ideas for new machines had deep insight: "hand-arm machines" [robots], manufacturing machines driven by specifications imprinted onto "perforated paper rolls" [NC machines], automatic inspection with sensors [Coordinate Measuring Machines]. In fact, Leaver and Brown's 'automatic factory' was driven from blueprints contained in a master record.

"In such a factory the human working force is confined to management, which makes the policy decisions as to how many of what items to produce, and an engineering and technical staff, which carries out the decisions. If a product is to be changed, new specifications for a new product in the form of punch cards or blueprint records are substituted for the old in the master record-control racks. Teams of technicians go down to the production floor to rearrange, set up, and reconnect the interchangeable units of production. Then the continuous production run is started again."

The first NC machine was developed at MIT in 1952; the first application of real time sensor based computer control was used by Texaco in 1959; and the first industrial robot to be used was installed in 1961. These developments were the building blocks for automated factories.

The first attempts at complete, controlled manufacturing of discrete parts were Flexible Manufacturing Systems. In 1967 Sundstrand Aviation installed the first FMS for the machining of aluminum pump parts and magnesium casting. (Hatvany, 1983).

In 1981, John Deere unveiled its new plant in Waterloo, Iowa (Dunolien et.al. 1981, 1983, Data Management 1981). John Deere Tractor Works won the LEAD Award for excellence in CIM given by the Society of Manufacturing Engineers. The plant has been recognized as an excellent example of CIM. It is also a good example of the understanding of the new paradigm for manufacturing.

In planning the new John Deere Tractor Works the company had three objectives: to provide products of advanced design, to assemble tractors in the most efficient way, and to provide company employees with a supervisory work environment. In order to accomplish this John Deere reorganized functional manufacturing into a cellular arrangement. Cells were established along lines of similar function with a view to efficient processing, routing and high machine utilization. Cellular manufacturing was part of an overall management strategy. The factory is composed of 19 cells which produce 600 different parts.

The benefits from this manufacturing approach are:

- a 25% reduction in the number of machine tools required
- a 70% reduction in the number of departments responsible for the manufacture of a part
- a 56% reduction in job change and material handling

- o an 8-to-1 reduction in required lead times and a corresponding reduction of inventory
- o shop supervisors now have more control over processing, with clear delineation of responsiblity

The factory is controlled by a hierarchy of computers. A host computer is used for production and inventory control. It communicates with several minicomputers which control parts routing, storage and manufacture in the cells, and which communicate in turn with microcomputers and programmable controllers to handle the production and transportation machines.

3.0 MYTHS ABOUT CIM

Contemporary articles on CIM, dealing with planning and implementation for the factory of the future, advocate several tenets as common sense wisdom about CIM. Many of these are myths and, if believed, would actually retard implementation of essential technology in the manufacturing sector. Some of these myths are outlined in an article by D.L. Shunk (Shunk, 1985); these and other myths are reviewed below.

3.1 CIM is a Complex Amalgamation of Methodology and Technology

One can readily disprove this myth by showing that the fundamental characteristics of a CIM environment can be understood and hence implemented. Realizable goals to strive for are:

- o reduction of economic order quantities
- o increase in inventory turns
- o increase in utilization of key machines
- o increase in product quality

The economic order quantity can be reduced by decreasing the cost for setup and for producing parts in small quantities. The use of Group Technology and process planning systems allow a choice of routing procedures and sequencing of operations in such a way that the processing of similar parts, in succession, on a machine may greatly reduce setup cost.

Inventory turn (the ratio of annual sales and the average inventory) is another performance characteristic which should be increased from the typical 4 to 10 per year to, hopefully, 1 per day. To achieve this, the inventory must to be reduced without risking stops in production due to the unavailability of parts. This requires up-to-date information about the location of inventory, both before and after its arrival at the plant. This requires integration of the vendor's and the manufacturer's inventory status information, as well as, integration of the enterprise's manufacturing and materials procurement functions. As an extra benefit, reduced inventory can streamline operations to provide the flexibility required to meet customer's orders and to effect changes quickly.

Machine utilization must be improved by identifying bottlenecks and adopting means to keep key machines productive. This can be achieved by reducing setup on those machines and by performing as many functions as possible off-line from the actual machining process.

As described earlier, inventory should be decreased as much as possible, and this requires just-in-time delivery of parts. However, these parts also have to be the right parts, with guaranteed quality at a good price. The most efficient way to produce a high quality product is to implement proactive quality assurance, which ensures the creation of a good part, rather than quality control, which is a reactive approach of inspection after the part's creation. This requires integration of process control parameters and product design specifications, as well as knowledge about the stage of the production cycle, appropriate process plans and information about the quality of purchased parts.

Each of the goals, described above, is achieved by improving information handling within manufacturing support systems. The integration of this information towards a single, master record will make the goals realizable and the benefits tangible. CIM is a simple concept which is easily achieved without complex technology.

3.2 CIM Processes Must Operate Faster to Produce More

This is definitely not the case. Key machines, which determine overall plant productivity are often utilized only 40 to 60%. An increase in process speed at fixed utilisation gives very little gain in process output [Fig. 1] compared to an increase in utilization. Besides, an increase in utilization requires less capital expenditure than an increase in process speed. In fact, an increase in utilization, with a decrease in process speed, may still lead to an increase in process output, while making it easier to monitor the location of parts in the manufacturing cycle and to capture other data. This facilitates the integration of production planning and control information. The improvement in data integrity may further increase productivity.

3.3 An Integrated Database Should Be Created First

The heart of a CIM environment is a database, with its associated architecture and communication links. However, it is not necessary, nor does it make economic sense, to implement the entire database at the start. What is required is the definition of the information and data needs of each business segment. The establishment of such an information model will lead to the implementation of those areas of the database which offer the greatest payback and which minimize disruptions of ongoing operations.

3.4 State-of-the-Art Systems Are the Key to CIM

If this is so, they are a poor key. Only about 20% of implemented manufacturing resource planning systems have achieved expected performance levels, and most flexible manufacturing systems perform at less than peak efficiency. Implementations of hardware and software alone have not solved the productivity problems. It is

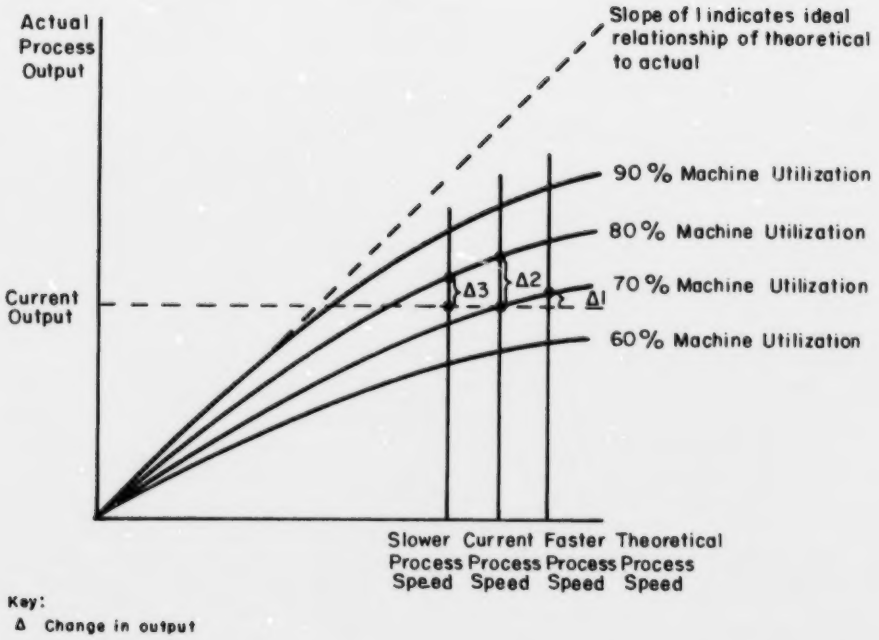

Fig. 1. (Adapted from D. L. Shunk)
Output Gain From Slowing Process Speed and Improving Machine Utilization

necessary to effect a complete, integrated solution and not just improve the efficiency of certain manufacturing facilities or steps in the process by using automation. The key is to involve management, staff, and users with social and data integrity issues, as well as with the hardware and software aspects. Well planned procedures, adequate support capability, data integrity and an integrated approach to productivity must complement hardware and software components to create an effective CIM system.

3.5 CIM Can Be Achieved by Integrating Islands of Automation

Some companies, in response to particular manufacturing needs, create 'islands of automation' by highly automating a particular area of specialization without regard to how the automation or the area of specialization relates to the rest of the facility. As a consequence these new areas of automation do not achieve the expected productivity improvement. Typically, there are poor interfaces from the new systems to the rest of the operation which limits their effectiveness.

In the previous example of bank operations, the banks could have created islands of automation by installing computers of different makes and sizes in each branch and automate only manual updating of customer's account cards. They wisely avoided this option.

Integration in a plant is accomplished by creating individual solutions based on common resources such as data, programming and computers. While already implemented islands of automation can be wired together in some fashion, they can never be truly integrated unless they are part of an overall plan.

4.0 CIM CONCEPTS

Besides the manufacturing area, most departments and sections of an enterprise operate as 'islands'. To satisfy their user requirements each group arrives at solutions involving hardware, data management, programming and communication structures. Usually these structures are appropriate only to the individual "island". In contrast CIM offers a management program for planning, funding and executing industrial automation projects to span the entire corporation.

4.1 Corporate Strategy

To move from the concept of operating 'islands' to CIM requires the creation of a corporate strategy to:

- o set corporate goals and provide a common focus
- o restructure departments and their functions
- o re-educate personnel in their new functions
- o set corporation wide standards

The CIM management program will serve as an umbrella under which specific projects are planned, financed, managed, and implemented. Well defined corporate goals must be set, and these may differ radically from previously perceived departmental goals. As each department strives toward common goals, integration and cooperation between departments becomes not only desirable but necessary. In the past, departmental budgets for automation were rarely spent on shared assets. Through an integration of financing strategies an enterprise can focus on capital investment in shared, value-added assets such as databases. These common assets are owned by the enterprise rather than by individual groups.

Integration may require that existing departments be restructured. For instance, in order to design parts suited for manufacture a close liaison between the design, engineering and manufacturing departments is necessary. Functions that were traditionally the responsibility of one department may, with the new goals in mind, become the responsibility of another department, or they may have to be expanded or eliminated entirely. This redefinition and reallocation of functions also affects the people performing these functions. People who have traditionally performed a particular function and have understood it well, in terms of their own mental model of how their functions worked, may require extensive re-education to appreciate how their new functions fit into the corporate scheme. They need to understand why the new definition of a particular function will be more effective in reaching the corporate goals, why some functions are no longer required, and why new ones have become necessary. They may also require re-training to perform their new functions.

The necessary integration requires common architectures for information, computer systems and data. The information architecture defines the information demand in terms of business processes and decision problems; the computer systems architecture defines technical standards for controlling the implementation of technology; and the data architecture defines standards for applications procurement and the development of shared databases. With these three architectures in place company wide access to the latest information, data and rules, is ensured. In addition, the storing of each of these items only once ensures their integrity.

4.2 Control Functions

Traditionally the selection of projects has been done within individual departments. If viewed from a company wide level, this may often appear random and arbitrary. Under a CIM program, projects should be selected and assigned priorities not by political needs but to provide leverage of assets. The projects should be based on corporate goals, not the traditional departmental goals. As the CIM projects are selected from the priority ranked list, the strategy should be to keep them small, in order to show tangible results in a reasonable time and to achieve a reasonable balance between acquiring assets and making assets available for specific user requirements.

Project management today is still an art rather than a science, and, as a consequence, project results vary greatly in quality and format. This may make integration of project results very difficult. To achieve quality and integrability in a CIM program the consistent management of projects is required. This means a structured approach to implementing solutions and it requires the establishment of company-wide standards to be applied to shared data, software development and computer technology.

Usually a lack of standards exists. Typically, in the traditional industrial automation management process, the only standards that are used are those that are already being conformed to by vendors of hardware and software, (i.e. the Initial Graphics Exchange Specifications or communications protocols, such as MAP). Very few corporation-wide standards are developed internally or used consistently for activities such as software development and testing, or for software package selection. However, for integration of the entire manufacturing operations of an enterprise, it is critical to set and adhere to standards.

Heavy involvement of users from all departments is necessary to define the users' requirements upon which these standards will be based. To respond to changing users' needs in the future, standards also have to be flexible and yet remain backward compatible.

Two types of standards are required. Externally defined technical standards are necessary to integrate and manage data management systems, computer hardware, operating systems and other automation hardware and associated communications equipment. Internally

generated standards define and manage information on parts, drawings, etc., as well as business rules. The technical standards provide the 'glue' which holds hardware and software components together. The internally generated standards provide unified operating procedures, data and information which are specific to the enterprise.

4.3 CIM Concept Summary

To summarize: CIM is a management program which is corporate driven to achieve well defined corporate goals. CIM projects operate under the umbrella of this management program. Information and data on all aspects of the enterprise's operation is stored, not necessarily centrally, but in a unique and well defined place. This ensures that every function requiring information or data uses the same source, and in this way data integrity is achieved. A high degree of integration of operations is brought about by common corporate goals, by a departmental structure that is based on these corporate goals, and by the use of a common source for information and data.

5.0 CIM MANAGEMENT ISSUES

When considering CIM technology there are several management issues which companies need to address. Solutions for the problems associated with these issues must be found to allow for the proper implementation of CIM. Management should consider these issues when planning for the installation of CIM technology so that an appropriate strategy can be adopted. These issues are discussed below.

5.1 Restructuring of the Organization

For the adoption of most technology a restructuring of management is usually not necessary. There are new responsibilities and duties, but the company structure or organization is ordinarily such that the new tasks can be handled well. However, for CIM there is a new model, a new way of thinking about manufacturing. Therefore, the adoption of CIM technology will change the way a company does manufacturing, the way in which managers must consider manufacturing, and the way in which responsibilities are allocated within the company.

The performance of middle management is crucial for the success of a business; it is crucial for the way in which manufacturing is performed. Middle management must be organized to respond to and take advantage of the new way in which CIM dictates that manufacturing be performed.

5.2 Cooperative Decision Making

As briefly discussed earlier, the existing manufacturing paradigm divides a company into separate cost centres, into separate decision centres, and into departments of specialization. The new paradigm requires that this be changed. Decisions must be based on the 'good' of the whole company, not just a small department. The sum of local optima is not an optimum for the whole.

Policies need to be put into place to resolve issues on a company wide basis. Because of this there must be input from all sections, and decisions, when made, need to be implemented across the company rapidly.

5.3 People as a Resource - Education

The greatest resource an enterprise has are the people associated with it. The issue associated with personnel is education; not just education in the skills of new technology, but education in a new way of thinking, of approaching corporate problems, and ofinteracting with the organization. This issue probably requires the most in-depth and careful consideration because the problems are largelypsychological and political.

5.4 Long Term Planning

CIM is a new technology, a new way of approaching manufacturing, and it requires long term planning. Present business practice requires management to put their major efforts towards short term goals. This is particularly true of public companies where the investment climate emphasizes quarterly performance reviews. CIM planning compels management to be long-term oriented, to be determined to reach company goals, and to have an evolutionary plan of migration using the new paradigm as its basis.

5.5 Control of Information

An important issue which must be considered is control of information. In the CIM model of manufacturing, all manufacturing, organizational and business knowledge is maintained and available in a single record. Knowledge is no longer distributed in the memories of several experienced people in an organization. This is both good and bad. It is good because it allows decisions to be made more rapidly and easily. It is bad because of the increase in information management and security problems. How does a company prevent information corruption, stealing and sabotage? This problem has been around in the data processing world for 20 years. CIM methodology makes this a critical issue since CIM forces a company to store its essence on computers as a single entity.

6.0 THE ROLE OF COMPUTERS

This paper has emphasized the importance of information handling and control with the use of CIM. With today's technology, computers provide the best tool for doing this. In a CIM environment computers efficiently perform:

- information processing
- data acquisition
- machine control (CAM)
- communications
- engineering analysis (CAE)
- design (CAD)

It should be noted that computers are not necessary for the working of the paradigm on which CIM technology is based. However, they do provide the best practical solution for most implementations.

In the 1970's there was great hope of developing large integrated manufacturing systems that involved machine control, processing information and manufacturing planning. These systems were never satisfactorily developed due to inappropriate system architectures and due to the very high cost of the needed computer power. Today this is no longer true, computers can do the job and do it economically. Computers are becoming smaller, faster and cheaper. The CIM paradigm is predicated on fast, reliable and inexpensive information storage and control. Today's computers provide this.

7.0 PROGNOSIS

CIM technology is a reality; the new paradigm will transform the manufacturing industry and society at large. What are some of the advances that will occur due to the drive to implement CIM technology? The manufacturing world has seen the development of computer graphics and the advent of CAD, of programming languages and control systems giving CAM, and of the computerization of analysis and engineering skills in CAE. For CIM there is the adoption and use of a great variety of computer skills that have been developed over the past two decades: control, communications, information processing and algorithm execution.

7.1 Technical

In the future, a great deal of work will be done on standards for automation and for computer systems. This will enable large manufacturing and business systems to be built where products are supplied from a range of companies not previously associated with each other. PC's (programmable controllers) are becoming more and more sophisticated and will continue to do so. Robots will have more adaptive control for better local decision making; automation will move in the direction of more autonomous control at lower levels of processing; machine controllers will have greater functionality and processing capability.

The electronics and computing industries will respond by making new IC's for manufacturing applications; computers will be smaller, faster and more rugged. Human interfaces will be made simpler and more application-oriented. There will be a greater emphasis on real time distributed computing, both locally and when connected to networks with a myriad of other types of information processing machines.

7.2 Manufacturing

The most important advance in manufacturing will be the ability to process products with a lot size of one; most manufacturing

will become make-to-order. This will permit a better response to user demands and a lower cost of goods overall. There will be new functions inside decision support systems to help managers plan and operate facilities and production tools.

7.3 Social

Within the work environment employees will be more skilled; there will be more generalists and fewer specialists. There will be less hands-on work and more supervisory tasks. There will be a reduction in the amount of labour employed in direct manufacturing and therefore, manufacturing support functions and support staff will be decreased.

The adoption of CIM technology and the CIM paradigm will take a few decades, but the effects will be far reaching and will impact on both the manufacturing environment and on the way in which goods are produced.

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4 CIM - A MANUFACTURING PARADIGM

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Automation, computer integration, integrated manufacturing, manufacturing management; flexible manufacturing
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SUMMARY/SOMMAIRE Presents CIM as a new paradigm which promotes the integration of organization, planning and control as a solution to improved productivity by maintenance of a single, manufacturing record.
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